BMP #20 - Riprap Slope and Outlet Protection

Targeted Pollutants

- ● Sediment
- ○ Phosphorus
- ○ Trace metals
- ○ Bacteria
- ○ Petroleum hydrocarbons

Physical Limits

Drainage area	5 ac
Max slope	40%
Min bedrock depth	N/A
Min water table	N/A
SCS soil type	ABCD
Freeze/Thaw	good
Drainage/flood control	no

DESCRIPTION

An arranged layer or pile of rock placed over the soil surface on slopes and at or below storm drain outfalls or temporary dikes.

Riprap used as slope protection protects against erosion and dissipates the energy of runoff or surface water flow. Outlet protection reduces the speed of concentrated storm water flows and thereby reduces erosion or scouring at storm water outlets. In addition, outlet protection lowers the potential for downstream erosion. This type of protection can be achieved through a variety of techniques, including stone or riprap outlet structures and armored scour holes installed below the storm drain outlet.

APPLICATIONS

For slope protection, use riprap or blanketed slopes. Outlet protection should be installed at the outlets of all pipes, culverts, catch basins, sediment basins, ponds, interceptor dikes, and swales or channel sections where the velocity of flow may cause erosion in the receiving channel. Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools (small, permanent pools located at an inlet or outfall).

Outlet protection should be installed early during construction activities, but may be added at any time, as necessary.

LIMITATIONS

The minimum particle size of the rock must be sized for the maximum expected velocity of flow out of the outlet and the soil conditions where the outlet will be located.

DESIGN PARAMETERS

The design of rock outlet protection depends entirely on the location. Pipe outlets at the top of cuts or on slopes steeper than 10 percent, cannot be protected by rock aprons or riprap sections due to reconcentration of flows and high velocities encountered after the flow leaves the apron.

Tailwater depth: The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. If the tailwater depth is less than half the diameter of the outlet pipe and the receiving stream is wide enough to accept divergence of the flow, it shall be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than half the pipe diameter and the receiving stream will continue to confine the flow, it shall be classified as a Maximum Tailwater Condition. Pipes which outlet onto flat areas with no defined channel may be assumed to have a Minimum Tailwater Condition.

Apron Size: The apron length and width shall be determined according to the tailwater condition.

If the pipe discharges directly into a well-defined channel, the apron shall extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank, whichever is less.

The upstream end of the apron, adjacent to the pipe shall have a width two (2) times the diameter of the outlet pipe, or conform to pipe end section if used.

Bottom Grade: The outlet protection apron shall be constructed with no slope along its length. There shall be no overfall at the end of the apron. The elevation of the downstream end of the apron shall be equal to the elevation of the receiving channel or adjacent ground.

Alignment: The outlet protection apron shall be located so that there are no bends in the horizontal alignment.

Materials: The outlet protection may be done using rock riprap, grouted riprap or gabions (BMP #19). Riprap size shall be based on calculated shear stress. It shall be composed of a well graded mixture of stone size so that 50 percent of the pieces, by weight, shall be larger than the d50 size determined by using the charts. A well graded mixture as used herein is defined as a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be 1.5 times the d50 size. Gabions to be installed in streambanks should be designed and installed according to Rule #9.3 of the Stream Channel Alterations, Rules and Regulations and Minimum Standards, Idaho Department of Water Resources, 1978.

Thickness: The minimum thickness of the riprap layer shall be 1.5 times the maximum tone diameter for d50 of 15 inches or less; and 1.2 times the maximum tone size for d50 greater than 15 inches. The following chart lists some examples:

ROCK RIPRAP SIZES AND THICKNESS

Unit shear stress (lb/ft2)	**d_{50} (inches)**	**d_{max} (inches)**	**Minimum blanket thickness (inches)**
0.67	2	4	6
2.00	6	9	14
3.00	9	14	20
4.00	12	18	27
5.00	15	22	32
6.00	18	27	32
7.80	21	32	38
8.00	24	36	43

Unit shear stress calculated as T = yds

where:

T = shear stress in lb/ft2

y = unit weight of water, 62.4 lb/ft3

d = flow depth in ft

s = channel gradient in ft/ft

Stone Quality: Stone for riprap shall consist of field stone or rough unhewn quarry stone. The stone shall be hard and angular and of a quality that will not disintegrate on exposure to water or weathering. The specific gravity of the individual stones shall be at least 2.5.

Recycled concrete equivalent may be used provided it has a density of at least 150 pounds per cubic foot, and does not have any exposed steel or reinforcing bars.

Filter: A filter is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into and through the riprap. Riprap shall have a filter placed under it in all cases.

A filter can be of two general forms: A gravel layer or a plastic filter cloth. The plastic filter cloth can be woven or non-woven monofilament yarns, and shall meet these base requirements: thickness 10-60 mils, grab strength 90-120 lbs; and shall conform to ASTM D-1777 and ASTM D-1682.

Gravel filter blanket, when used, shall be designed by comparing particle sizes of the overlying material and the base material. Design criteria is available in any soils or civil engineering reference or from the National Resources Conservation Service (formerly the Soil Conservation Service).

DESIGN PROCEDURE AND EXAMPLES

1. Investigate the downstream channel to assure that non-erosive velocities can be maintained.

1. Determine the tailwater condition at the outlet to establish which curve to use.

1. Enter the appropriate chart with the depth of flow and discharge velocity to determine the riprap size and apron length required. It is noted that references to pipe diameter in the charts are based on full flow. For other than full pipe flow, the parameters of depth of flow and velocity must be used.

1. Calculate apron width at the downstream end if a flared section is to be employed

Example 1: Pipe Flow (full) with discharge to unconfined section

A circular conduit is flowing full:

Q = 280 cfs, diam. = 66", tailwater (surface) is 2 ft. above pipe invert, (minimum tailwater condition)

Read d_{50} = 1.2', and apron length 38'

Apron width = diam. + L_a = 5.5 + 38 = 43.5'

Example 2: Box Flow (partial) with high tailwater

A box conduit discharging under partial flow conditions. A concrete box 5.5' x 10' is flowing 5.0' deep, Q = 600 cfs and tailwater surface is 5' above invert (Max. tailwater condition).

V = Q = 600 = 12 fps

A 5x10

At the intersection of the curve d = 60" and V = 12 fps, read d_{50} = 0.4'

Then reading to the d = 60" curve, read apron length = 40'

Apron width, W = conduit width + 0.04 L_a = 10+(0.4) (40) = 26'

Example 3: Open Channel Flow with Discharge to Unconfined Section

A trapezoidal concrete channel 5' wide with 2:1 side slopes is flowing 2' deep, Q = 180 cfs (velocity = 10 fps) and the tailwater surface downstream is 0.8' (minimum tailwater condition).

At intersection of the curve d-24' and V = 10 fps, read d_{50} = 0.7'

Then reading up to the d = 24" curve, read apron length = 22'

Apron width, W = bottom of width of channel + L_a = 5 + 22 = 27'

Example 4: Pipe flow (partial) with discharge to a confined section

A 48" pipe is discharging with a depth of 3', Q = 100 cfs, and discharge velocity of 10 fps (established from partial flow analysis) to a confined trapezoidal channel with a 2' bottom, 2:1 side slopes, n = .04, and grade of 0.6%.

Calculation of the downstream channel (by Manning's Equation) indicates a normal depth of 3.1' and normal velocity of 3.9 fps.

Since the receiving channel is confined, the maximum tailwater condition controls.

At the intersection of d = 36" and v = 10 fps, Read d_{50} = 0.3'

Reading up to the d = 36" curve, read apron length = 30'

Since the maximum flow depth in this reach is 3.1', that is the minimum depth of riprap to be maintained for the entire length.

CONSTRUCTION GUIDELINES

- The subgrade for the filter, riprap or gabion shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density of approximately that of the surrounding undisturbed material

- The rock or gravel shall conform to the specified grading limits when installed respectively in the riprap or filter

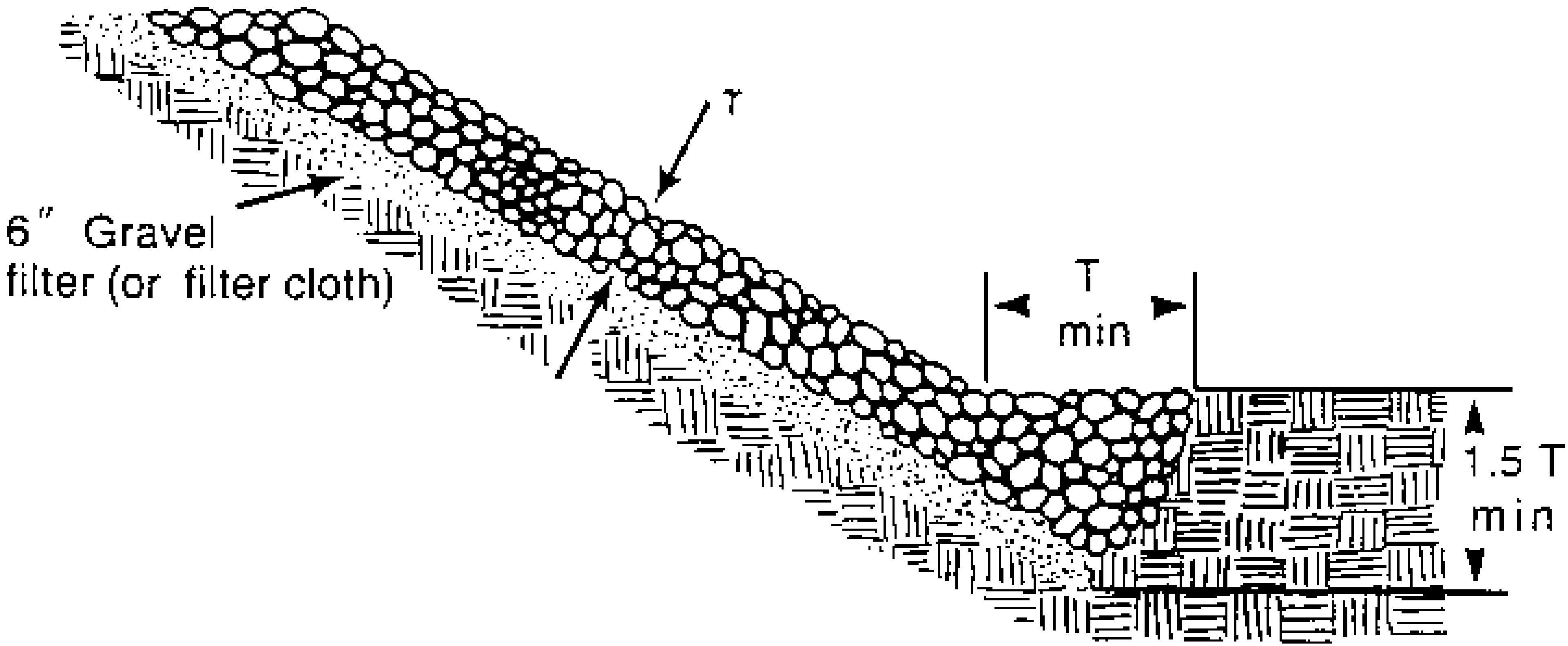
- Filter cloth shall be protected from punching, cutting, or tearing. Any damage other than an occasional small hole shall be repaired by placing another piece of cloth over the damaged part or by completely replacing the cloth. All overlaps whether for repairs or for joining two pieces of cloth shall be a minimum of one foot.

- Stone for the riprap or gabion outlets may be placed by equipment. Both shall be constructed to the full course thickness in one operation and in such a manner as to avoid displacement of underlying materials. The stone for riprap or gabion outlets shall be delivered and placed in a manner that will insure that it is reasonably homogenous with the smaller stones and spalls filling the voids between the larger stones. Riprap shall be placed in a manner to prevent damage to the filter blanket or filter cloth. Hand placement will be required to the extent necessary to prevent damage to the permanent works.

- Complete construction of the outlet protection before allowing erosive flows to pass through the outlet.

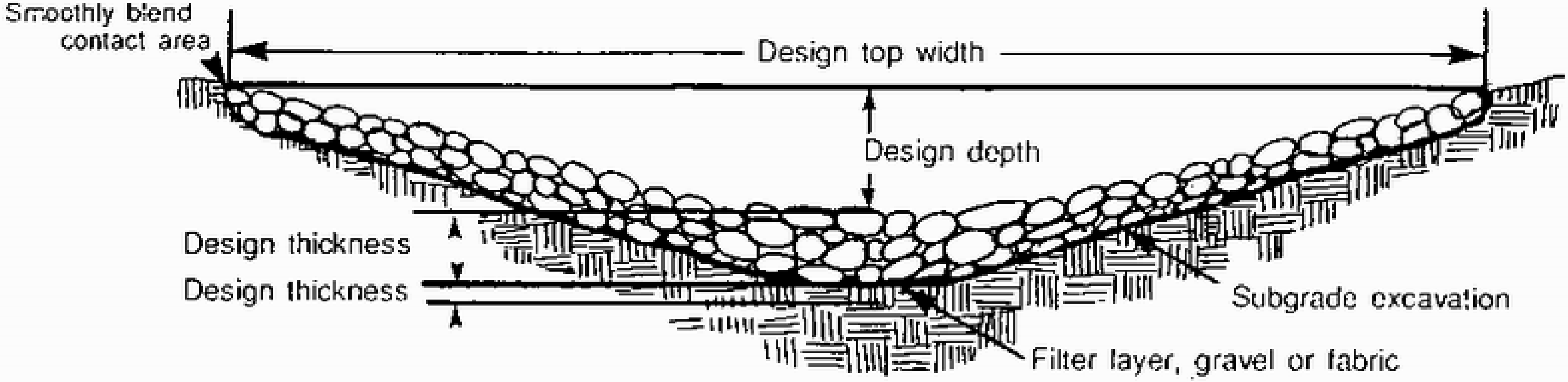
MAINTENANCE

Once a riprap outlet has been installed, the maintenance needs are relatively low. Inspect after heavy storms and high flows for scouring under the outlet and dislodged stones, and repair damage promptly. For dikes, maintain the area upstream of the outlet structure so that accumulated sediments can be removed when they reach a depth of one-third the height of the dike, or 12 inches (300 mm), whichever is less.

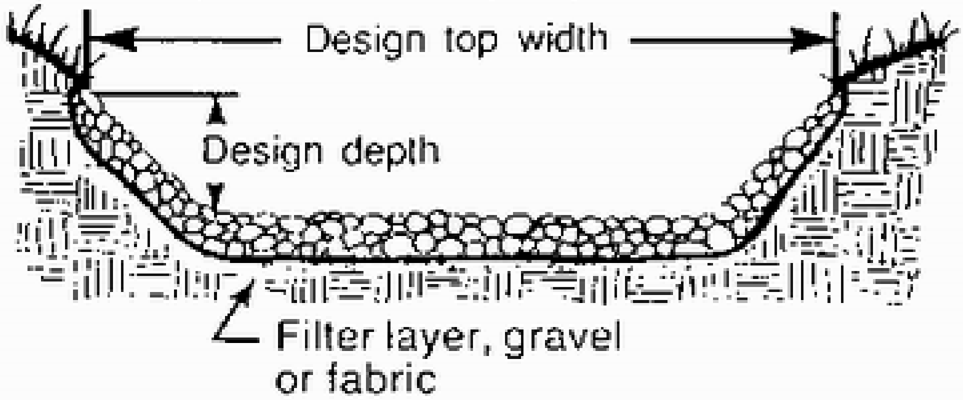


T
6" Gravel
filter (or filter cloth)
T
min
1.5 T
min

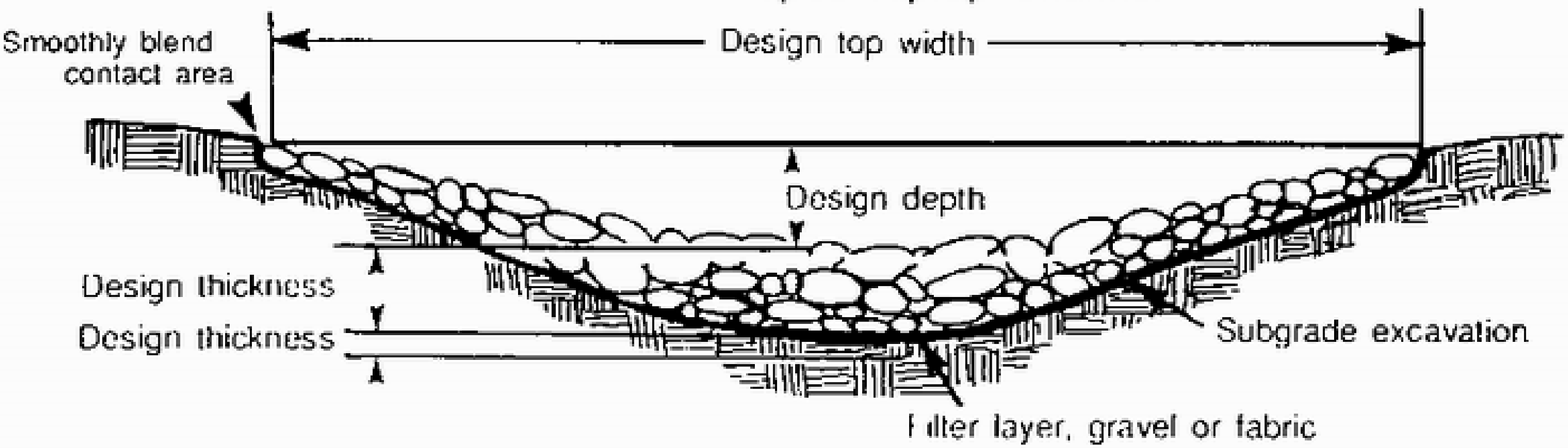
V-shaped Riprap Channel

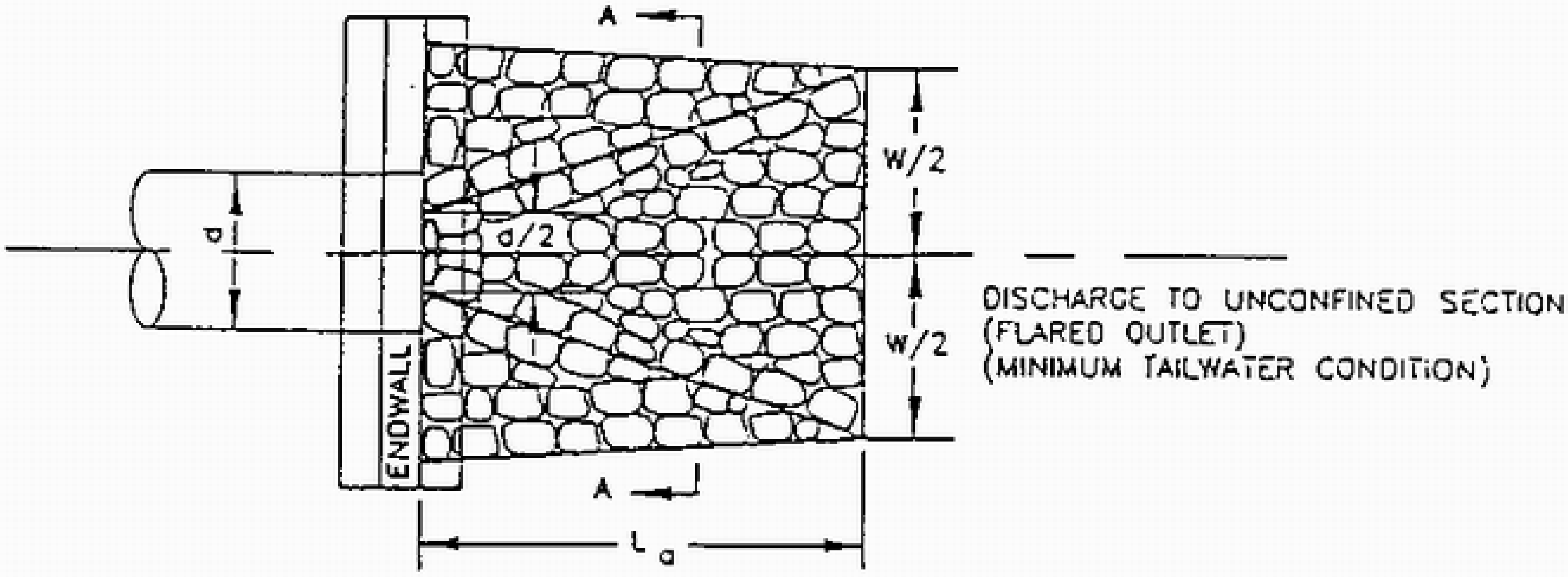


Trapezoidal Riprap Channel

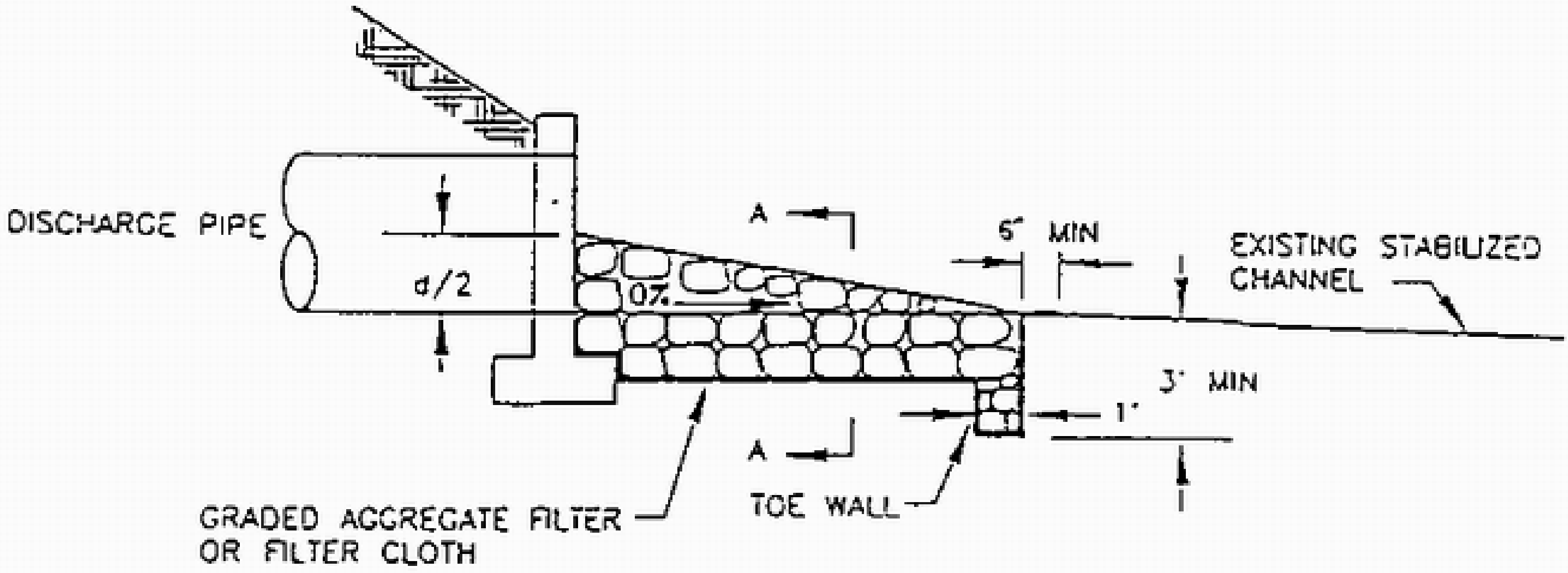


Parabolic-shaped Riprap Channel

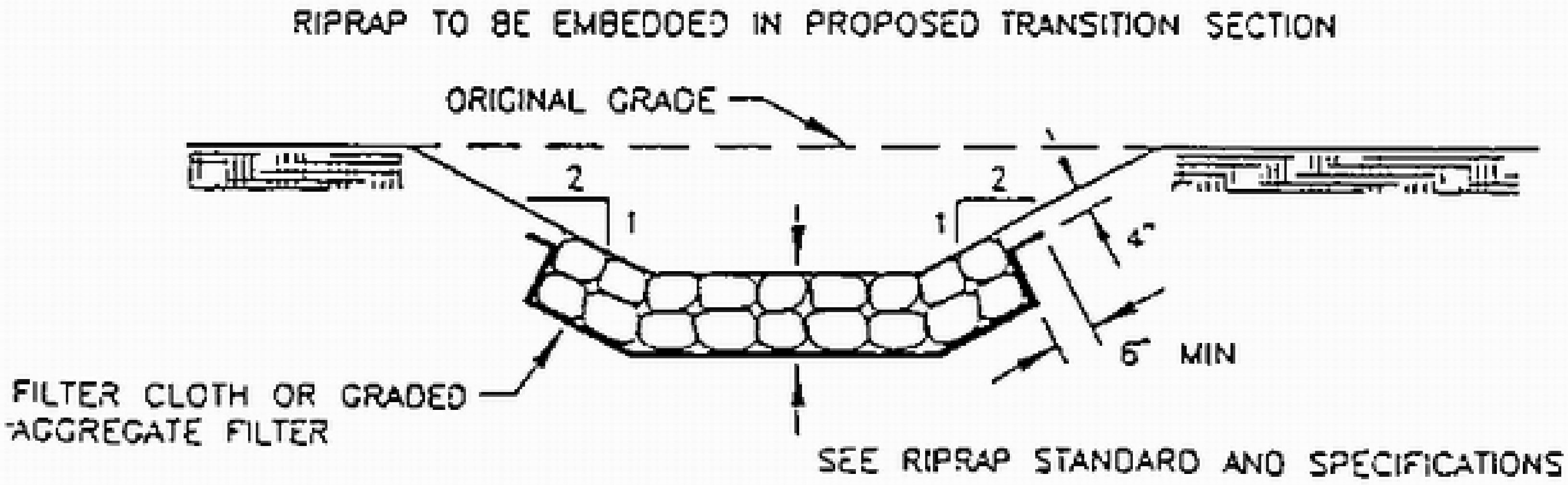




PLAN VIEW

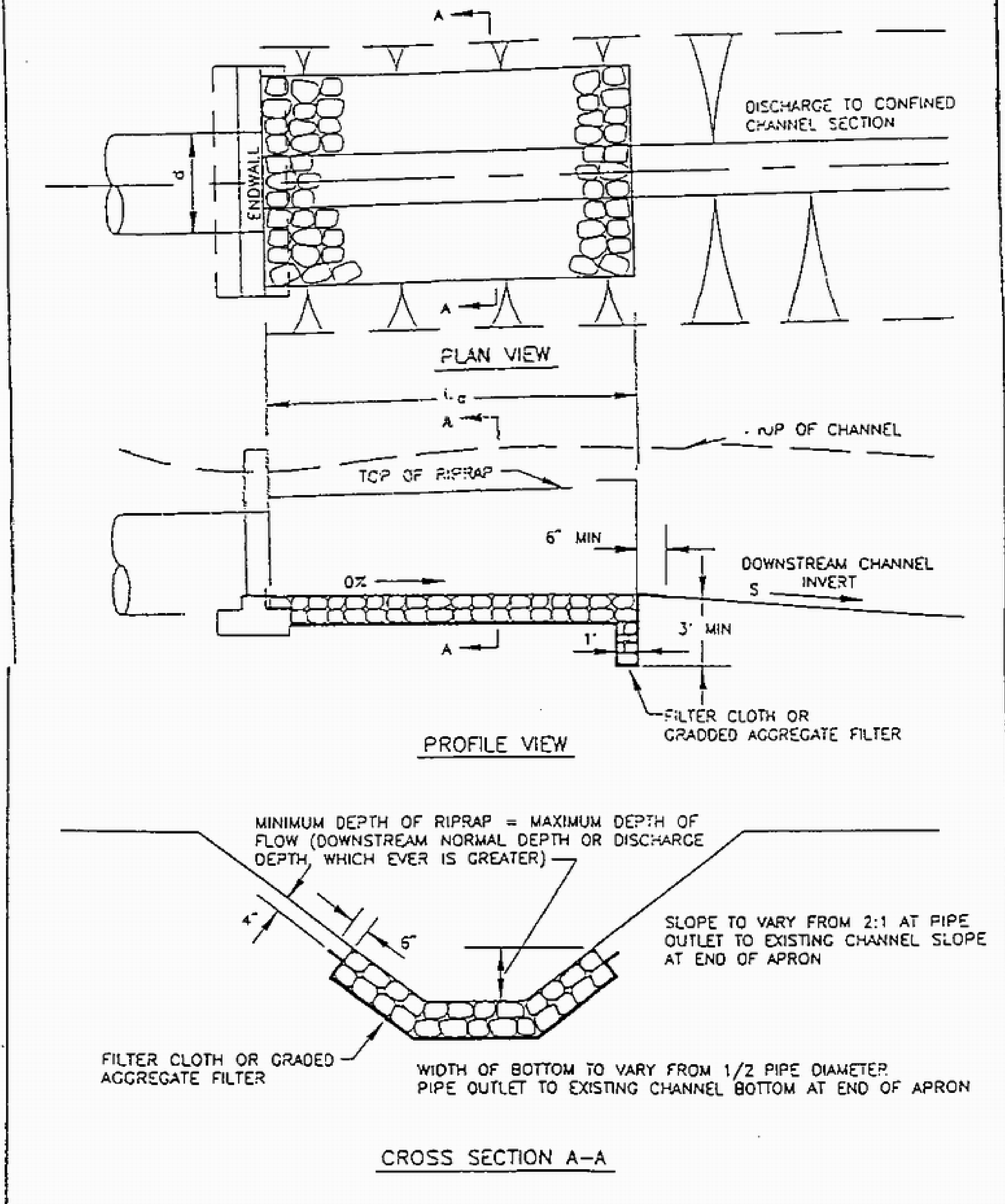


PROFILE VIEW

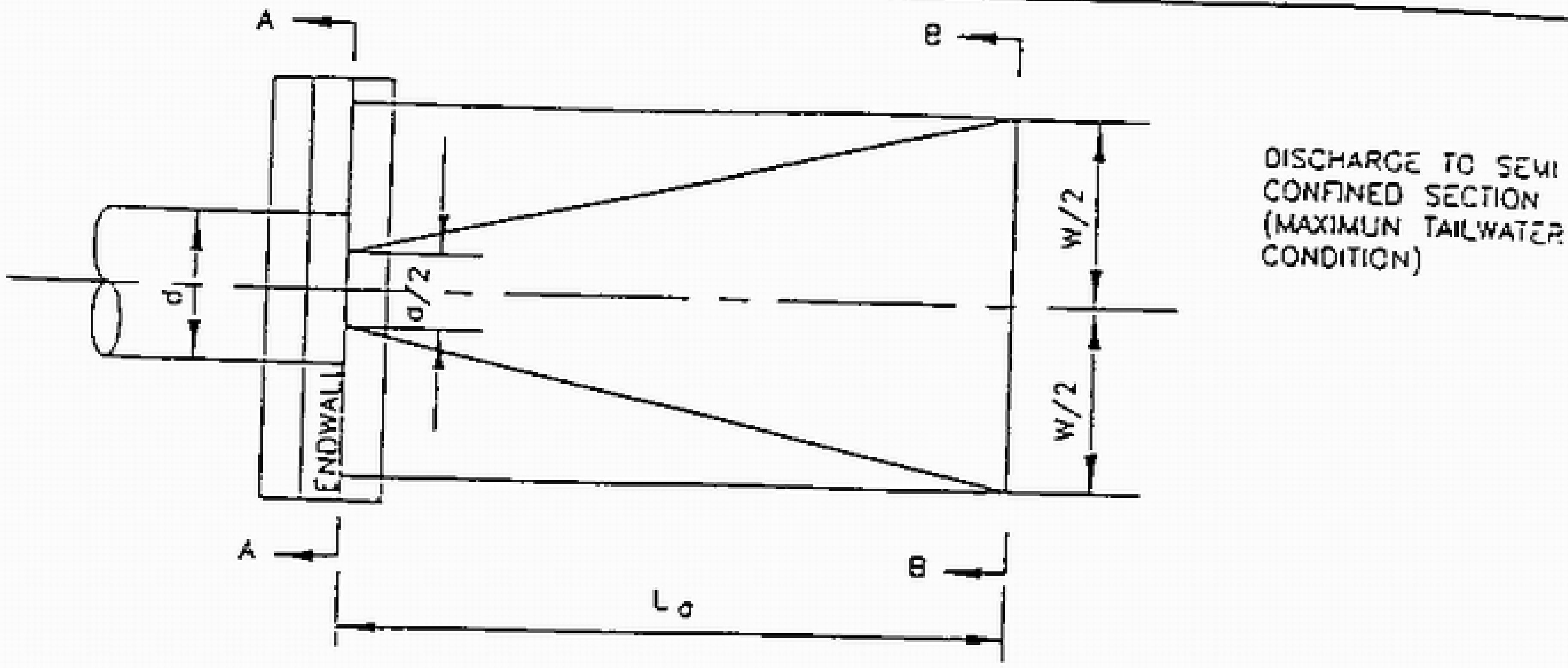


CROSS SECTION A-A

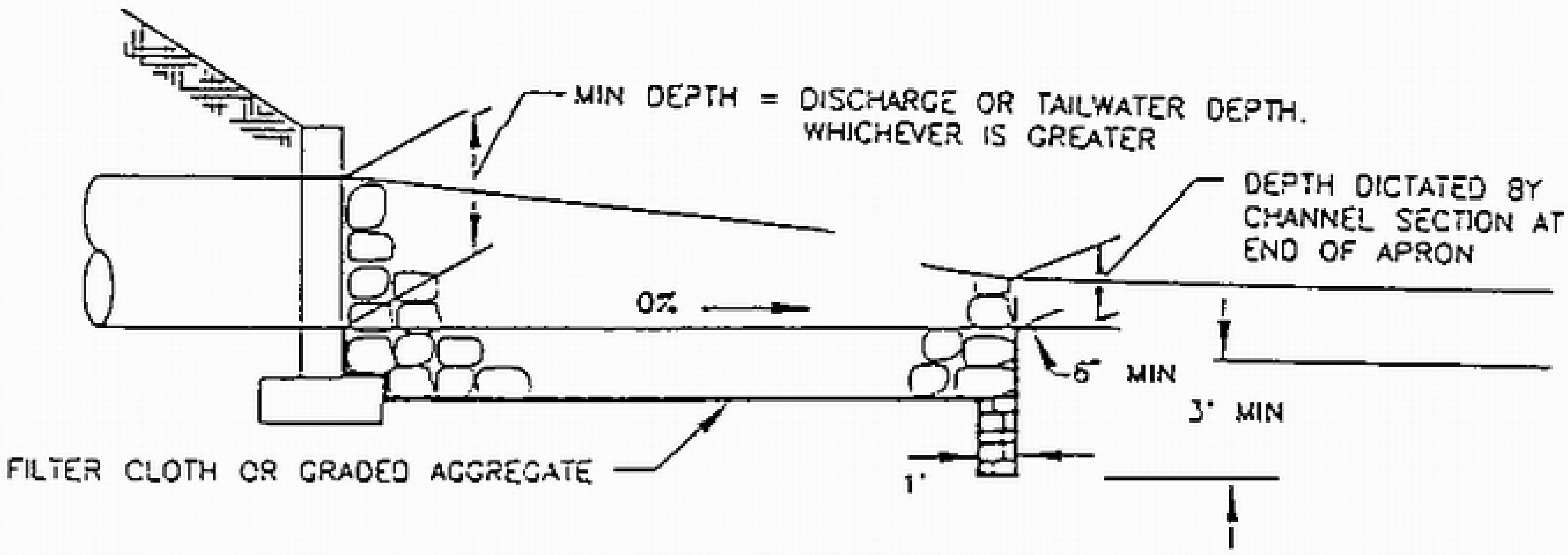
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	RIPRAP OUTLET PROTECTION - I	STANDARD DRAWING
TOOTHMAN-ORTON ENGINEERING COMANY BOISE, IDAHO McCALL, IDAHO		ROP-I



U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	RIPRAP OUTLET PROTECTION — II	STANDARD DRAWING
TOOTHMAN-ORTON ENGINEERING COMANY BOISE, IDAHO McCALL, IDAHO		ROP-II

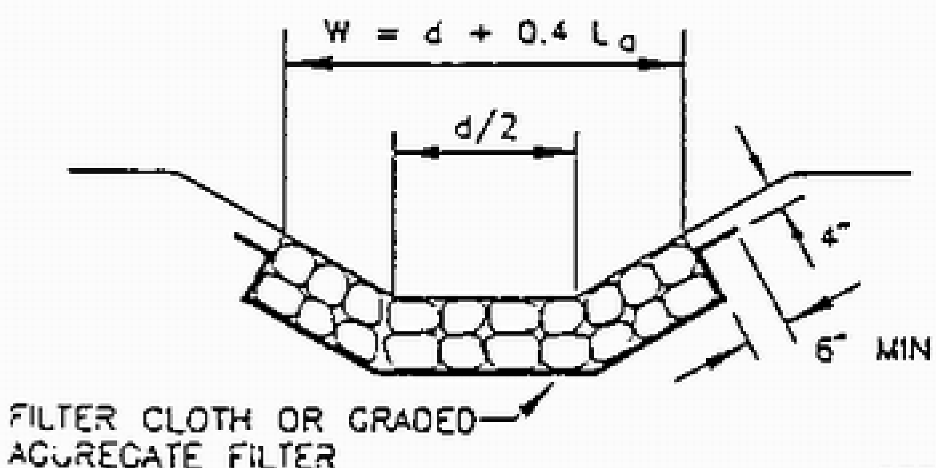


PLAN VIEW



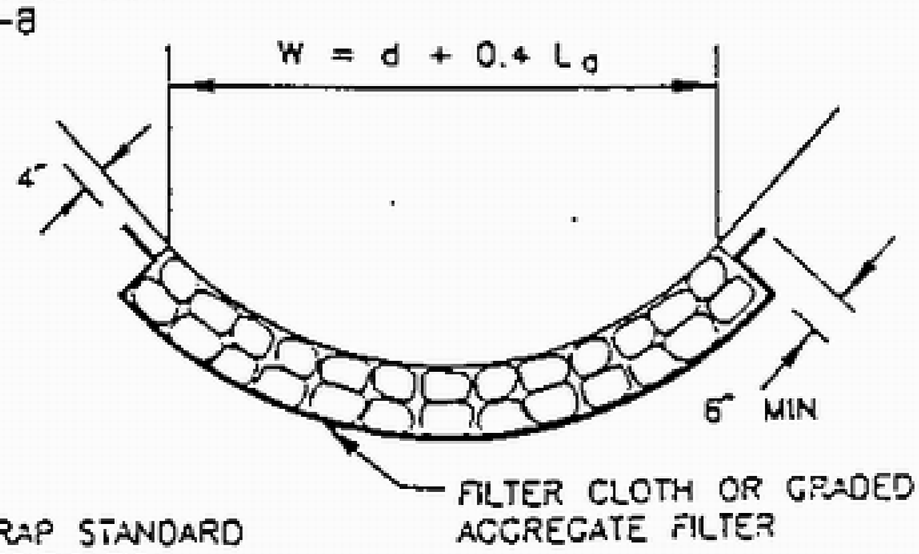
PROFILE SECTION

CHANNEL SECTION TO VARY FROM A-A TO B-B



CROSS SECTION A-A

SEE RIPRAP STANDARD AND SPECIFICATION



CROSS SECTION B-B

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	RIPRAP OUTLET PROTECTION - III	STANDARD DRAWING
TOOTHMAN-ORTON ENGINEERING COMANY BOISE, IDAHO McCALL, IDAHO		ROP-III